

Ecology and the environment revision notes

Ecology is the study of how organisms interact with each other and with their environment. This topic covers how populations are studied and what affects them, how energy and substances pass along food chains, how the carbon cycle recycles materials, and how human activities such as pollution affect the environment.

For Edexcel International GCSE Science (Double Award) 4SD0.

1 The organism in the environment Spec 4.1-4.5

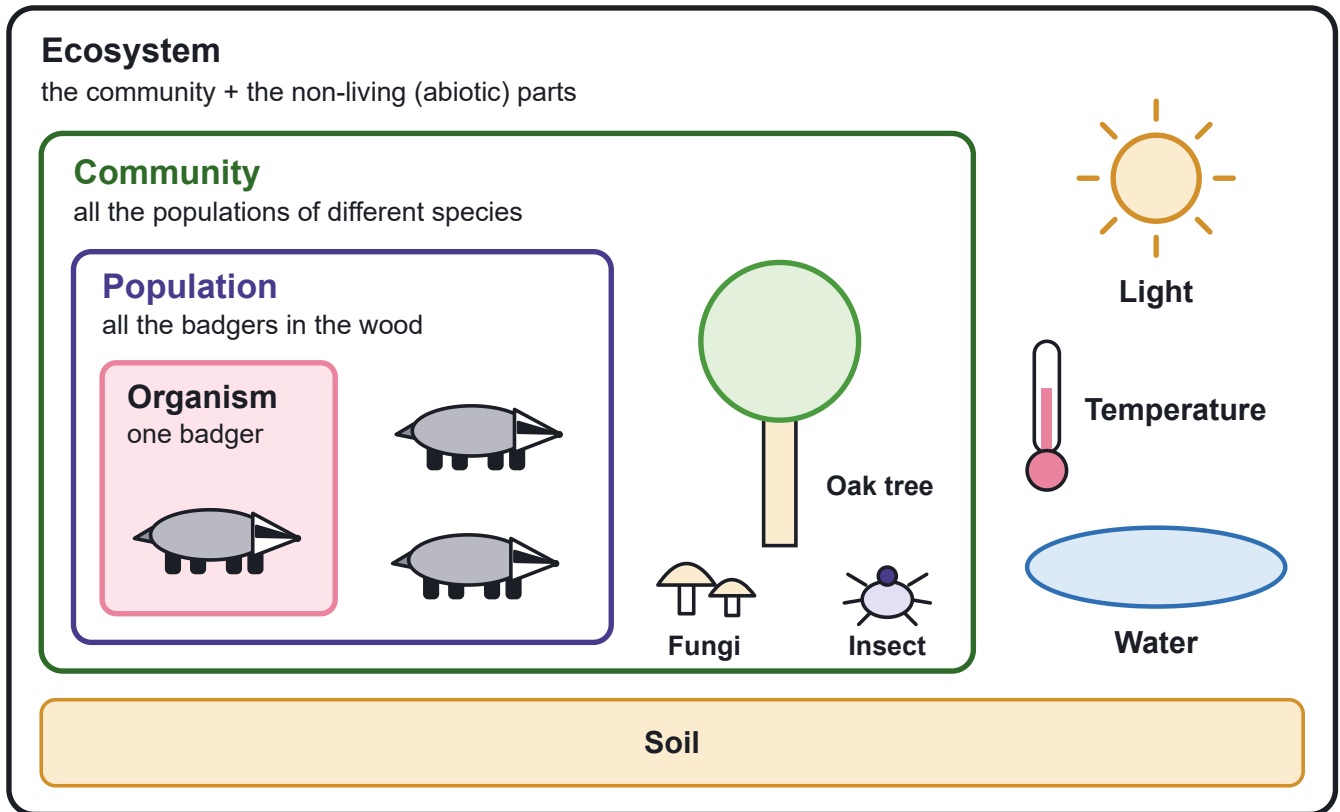
Population, community, habitat and ecosystem Spec 4.1

Ecologists use four key terms to describe living things and where they live. Each one covers a bigger scale than the one before.

Key ecological terms		
Term	What it means	Example
Population	All the organisms of one species living in the same area	All the badgers in a wood
Community	All the populations of different species living in the same area	The badgers, foxes, oak trees, insects and fungi in the wood
Habitat	The place where an organism lives	The woodland floor, or a pond
Ecosystem	A community together with the non-living (abiotic) parts of its environment	The wood, including its soil, water, light and temperature

An **ecosystem** is made of living (**biotic**) and non-living (**abiotic**) parts that interact with each other. Energy and materials move between them.

Common mistake: A population is one species only. If an answer mentions different species living together, it is describing a community.



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Each level contains the one before it: **organism**, **population**, **community**, then **ecosystem** (the community plus its abiotic parts).

Practical: population size with quadrats Spec 4.2

To compare the population size of an organism in two different areas, you cannot count every individual. Instead you take samples using a **quadrat**, a square frame that marks out a small, known area.

Quadrat

A square frame used to sample the organisms in a small, known area.

Method: comparing two areas

1. Choose the two areas to compare, for example a shaded area under a tree and an open, sunny area of the same lawn.
2. In the first area, lay two tape measures at right angles along two sides to make a grid.
3. Use a **random number generator** to pick two coordinates, one along each tape measure.
4. Place the quadrat at that point and count the number of the chosen species (for example daisies) inside it.
5. Repeat for at least 10 quadrats, then calculate the **mean number per quadrat**.
6. Repeat the same steps in the second area, using the same size of quadrat and the same number of quadrats.
7. Compare the two means.

Variables and safety

- **Independent variable:** the area (for example shaded or open).
- **Dependent variable:** the number of the chosen species per quadrat.
- **Control variables:** the size of the quadrat, the number of quadrats, the species counted, the person counting and the time of year.

- **Safety:** wear suitable footwear, wash hands after handling soil or plants, and do not touch plants you cannot identify.

Practical: Say that quadrats are placed randomly to avoid bias, and that using many quadrats makes the mean more reliable. The same number of quadrats must be used in each area for a fair comparison.

Typical result: if one area has more light or water, the mean number of a plant that needs these will be higher there. The mean from each area is then used to estimate the whole population, as shown in the next section.

Estimating population size Spec 4.2

You cannot count every organism in a large area, so you count the organisms in a sample of quadrats and scale up the mean to the whole area.

estimated population = mean number per quadrat × (total area ÷ area of one quadrat)

Estimating a population

A student counted daisies in five 0.25 m² quadrats placed randomly in a field of area 100 m². The counts were 3, 5, 4, 6 and 2. Estimate the number of daisies in the field.

1. Mean per quadrat = $(3 + 5 + 4 + 6 + 2) \div 5 = 20 \div 5 = 4$
2. Number of quadrat areas in the field = $100 \div 0.25 = 400$
3. Estimated population = $4 \times 400 = 1600$

Answer: 1600 daisies

Plants that are difficult to count individually, such as grass, can be measured by **percentage cover**: the percentage of the quadrat covered by the species.

- Take as many quadrats as possible, because a bigger sample is more representative and reduces the effect of anomalies.
- Place quadrats randomly, to avoid bias.
- Calculate a **mean** from the raw data. A bar chart or frequency table is useful for presenting the results.

Maths skill: Check the units. If the quadrat is 0.5 m by 0.5 m its area is 0.25 m², not 0.5 m². This is the most common slip in estimate questions.

Abiotic and biotic factors Spec 4.5

The population size and distribution of organisms are affected by **abiotic factors** (non-living) and **biotic factors** (living). Changes in either can change which species live in a place and how many there are.

Factors that affect populations

Type	Factor	How it can affect population size and distribution
Abiotic	Temperature	Affects the rate of enzyme-controlled reactions, so growth and survival. Species survive only within a range of temperatures.
Abiotic	Light	Plants need light for photosynthesis. Less light means fewer plants, and so less food for the animals that depend on them.
Abiotic	Water	All organisms need water. In dry conditions only organisms adapted to save water survive, so numbers and variety fall.
Biotic	Competition	Organisms of the same or different species compete for the same limited resources, such as food, water, light and space.
Biotic	Predation	Predators eat prey, so predator and prey numbers affect each other.

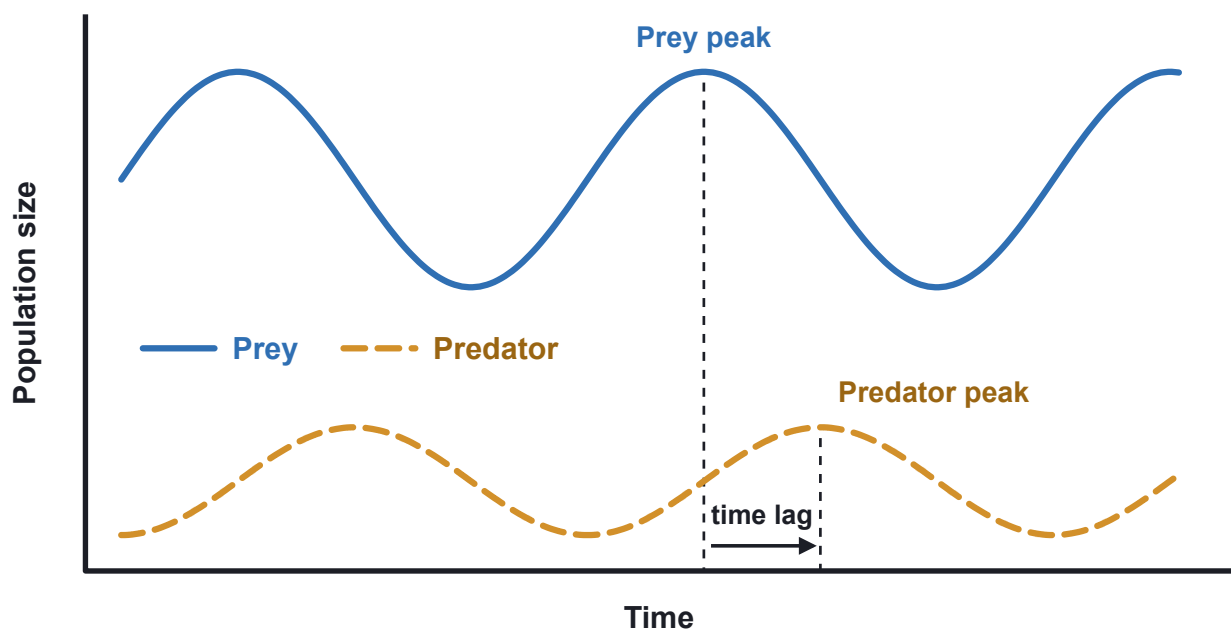
Competition

Competition happens when organisms need the same resource and there is not enough for all of them. Plants compete for light, water and mineral ions. Animals compete for food, water and territory. The better-adapted species gets more of the resource, so it survives and reproduces more, and the numbers of the other species may fall.

Predation

In a stable community, predator and prey numbers rise and fall in a repeating pattern. When prey numbers rise, predators have more food, so predator numbers rise. More predators eat more prey, so prey numbers fall. With less food, predator numbers then fall, and the prey can recover.

Exam tip: On a predator-prey graph, the predator peak comes after the prey peak, because predator numbers rise only once there is more food.



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Predator and prey numbers cycle: the predator peak comes after the prey peak.

Quick check

- 1 . What is a population?
- 2 . What is an ecosystem?
- 3 . Why are quadrats placed randomly?
- 4 . Name two biotic factors that affect population size.

2 Feeding relationships Spec 4.6-4.9

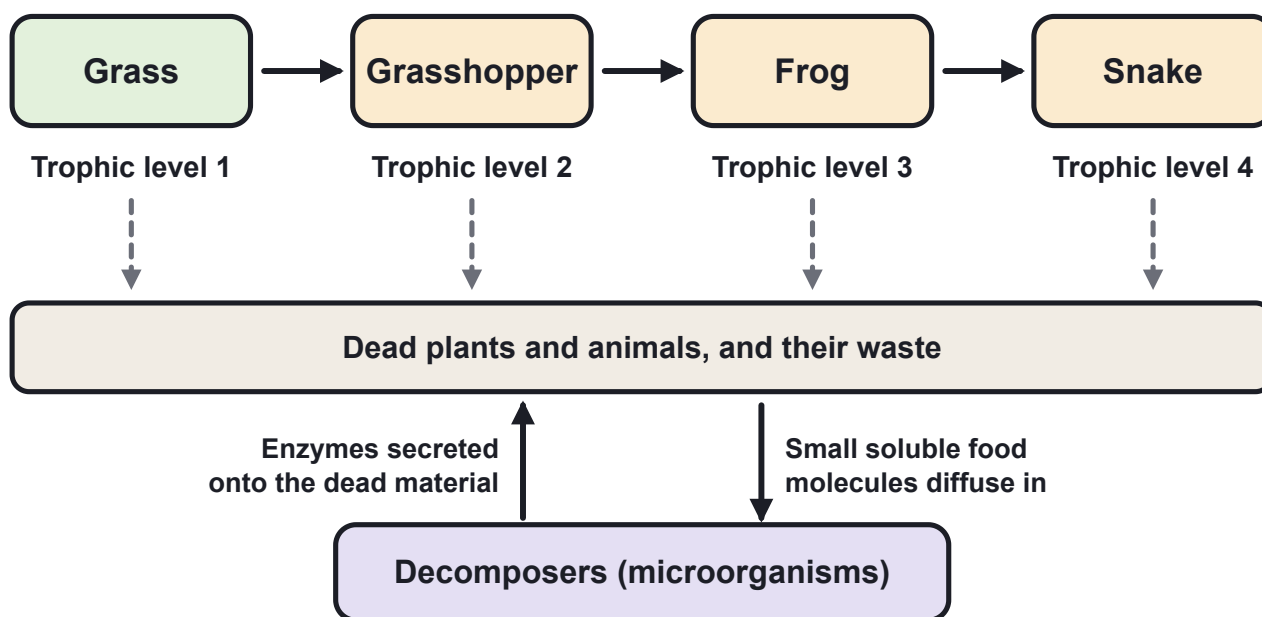
Trophic levels Spec 4.6

A **trophic level** is the position of an organism in a food chain. Trophic levels are numbered, starting at level 1 with the producers. Further levels are numbered according to how far the organism is along the food chain.

Trophic level	Organisms	Name
Level 1	Plants and algae make their own food	Producers
Level 2	Herbivores eat the producers	Primary consumers
Level 3	Carnivores that eat herbivores	Secondary consumers
Level 4	Carnivores that eat other carnivores	Tertiary consumers

Decomposers

Decomposers break down dead plant and animal matter and waste by secreting enzymes into the environment. Small soluble food molecules then diffuse into the microorganism. Decomposers are bacteria and fungi.



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Every trophic level ends up as dead material or waste. Decomposers **secrete enzymes** onto it, then the small soluble molecules diffuse in.

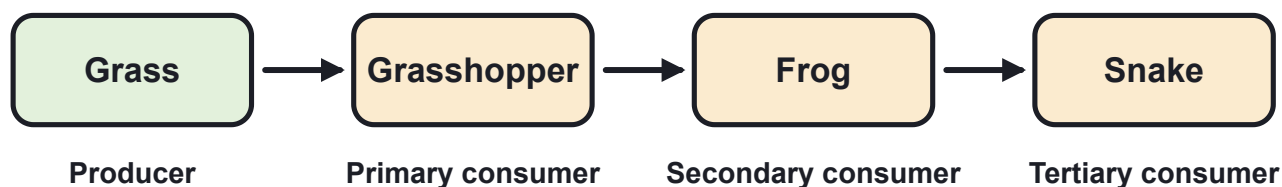
Exam tip: *Decomposers secrete enzymes outside their bodies, onto the dead material. They do not take in the dead material and then digest it.*

Food chains and food webs Spec 4.7

Feeding relationships in a community can be shown by **food chains**. All food chains begin with a **producer**, usually a green plant or alga that makes glucose by photosynthesis. The arrows show the direction in which food, and so energy and substances, pass.

Feeding levels in a food chain		
Name	What it does	Example
Producer	Makes glucose by photosynthesis	Grass
Primary consumer	Eats the producer	Grasshopper
Secondary consumer	Eats the primary consumer	Frog
Tertiary consumer	Eats the secondary consumer	Snake

Consumers that kill and eat other animals are **predators**, and those eaten are **prey**.



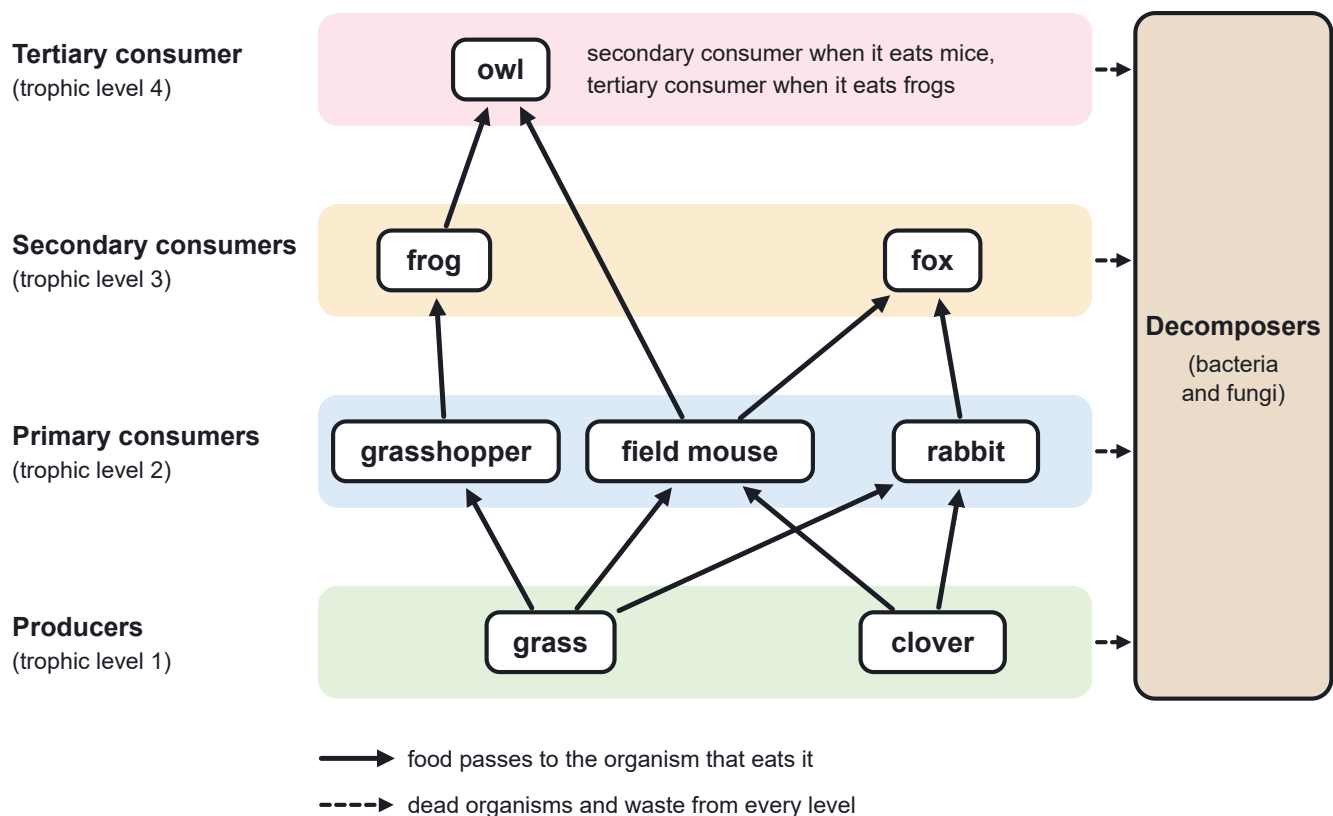
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The arrows show the direction the food goes: from the food to the animal that eats it.

Food webs

Most organisms eat more than one type of food, and are eaten by more than one type of predator. A **food web** shows how all the food chains in a habitat are linked together. In a food web an organism can be at more than one trophic level. For example, an owl that eats mice and also eats shrews that have eaten beetles is both a secondary and a tertiary consumer.

Because the food chains are linked, a change in the population of one organism can affect many others. If one prey species dies out, its predators may eat more of another prey species, whose numbers then fall.



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The owl feeds at **two trophic levels**: a secondary consumer when it eats mice and a tertiary consumer when it eats frogs.

Common mistake: Arrows in a food chain or web point from the food to the animal that eats it. Grass → rabbit means the rabbit eats the grass.

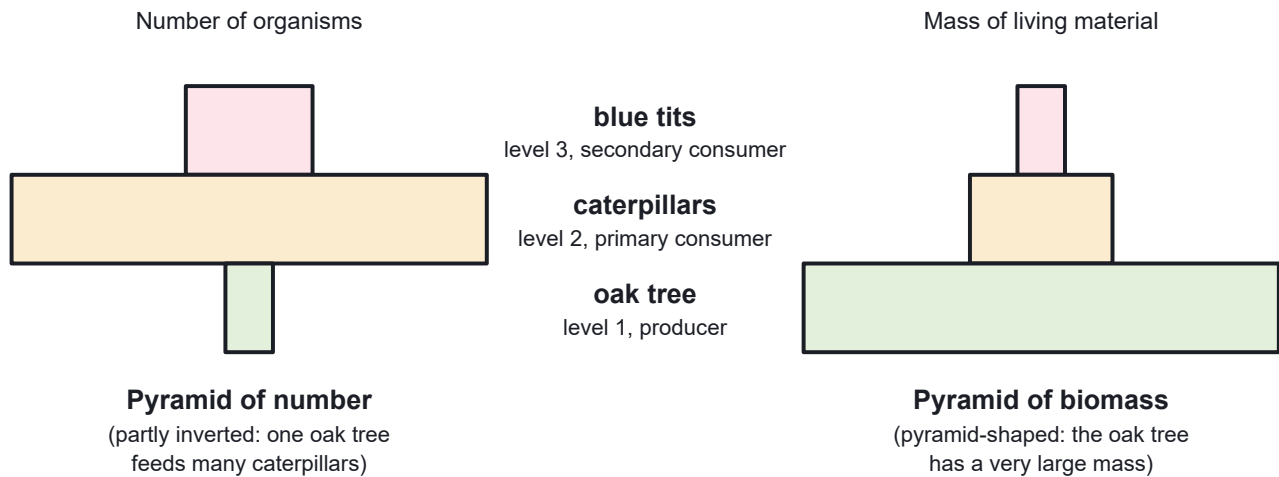
Pyramids of number, biomass and energy Spec 4.7

Pyramids use bars to compare the trophic levels in a food chain, with trophic level 1 at the bottom. There are three types.

Types of ecological pyramid		
Pyramid	What each bar shows	Shape
Pyramid of number	The number of organisms at each trophic level	Often a pyramid, but can be inverted
Pyramid of biomass	The mass of living material at each trophic level	Almost always narrows at each level
Pyramid of energy transfer	The amount of energy transferred to each trophic level, for example in kJ per m ² per year	Always narrows at each level

Pyramids of number

A pyramid of number counts the organisms but ignores their size. Where one large producer supports many small consumers, such as one oak tree supporting thousands of caterpillars, the bottom bar is narrower than the bar above it, so the pyramid is not pyramid-shaped. It is partly or fully **inverted**. Parasites can do the same: one fox may carry hundreds of fleas. A pyramid of biomass for the same chain is pyramid-shaped, because the oak tree has a very large mass.



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The same food chain: the **pyramid of number is inverted**, but the pyramid of biomass is pyramid-shaped.

Pyramids of biomass

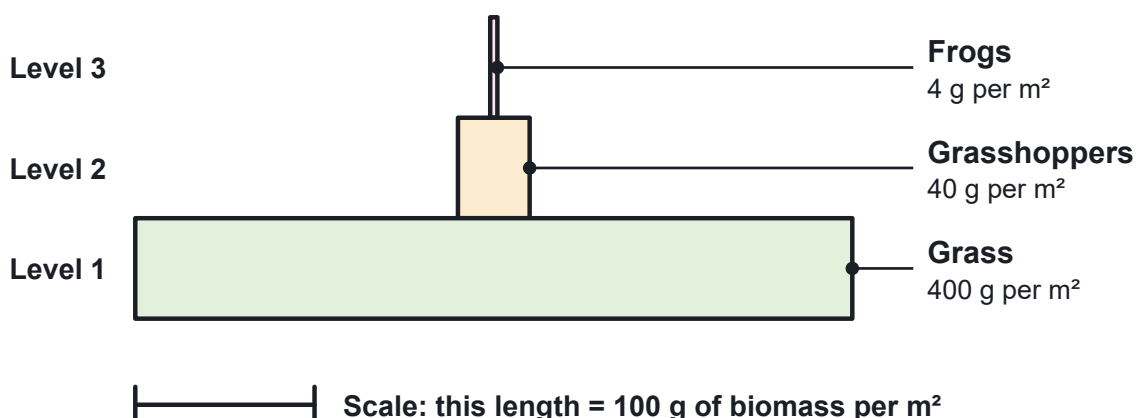
Each bar shows the mass of living material at that trophic level, and it almost always gets narrower at each higher level. To draw one, choose a scale so the length of each bar is proportional to its biomass, put trophic level 1 at the bottom and centre the bars on a vertical line.

Drawing a pyramid to scale

A food chain has biomass of 400 g per m² of grass, 40 g per m² of grasshoppers and 4 g per m² of frogs. Describe how to construct the pyramid using a scale of 1 mm = 4 g.

1. Grass: $400 \div 4 =$ a bar 100 mm long, at the bottom.
2. Grasshoppers: $40 \div 4 =$ a bar 10 mm long, above the grass.
3. Frogs: $4 \div 4 =$ a bar 1 mm long, at the top.

Answer: Three centred bars of 100 mm, 10 mm and 1 mm, with grass at the bottom and frogs at the top.



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The pyramid from the worked example, drawn to scale. Each bar is about **10%** of the one below it.

Pyramids of energy transfer

A pyramid of energy transfer shows how much energy is transferred to each trophic level in a given time. It is always pyramid-shaped, because energy is lost at every step, so each level receives less than the one below.

Exam tip: Pyramids of number are often inverted. Pyramids of energy transfer never are. If a question shows a pyramid that is not pyramid-shaped, it is most likely a pyramid of number.

Energy transfer and the 10% rule Spec 4.8, 4.9

Producers absorb only a small part of the light energy that reaches them. The energy stored in their biomass is passed along the food chain, together with the substances (such as carbon compounds) that make up the biomass, when each organism is eaten by the next.

Energy is not passed on completely. Only about **10%** of the energy is transferred from one trophic level to the next. The rest is lost, for these reasons:

- not all of the organism is eaten (for example bones, roots or hair), and some of what is eaten is not digested and is lost in faeces;
- energy is released by **respiration** and transferred to the surroundings as heat;
- energy is used for movement and for keeping warm in mammals and birds;
- energy is lost in waste such as urine.

percentage of energy transferred = energy transferred to the next level ÷ energy available at the previous level × 100

Percentage of energy transferred

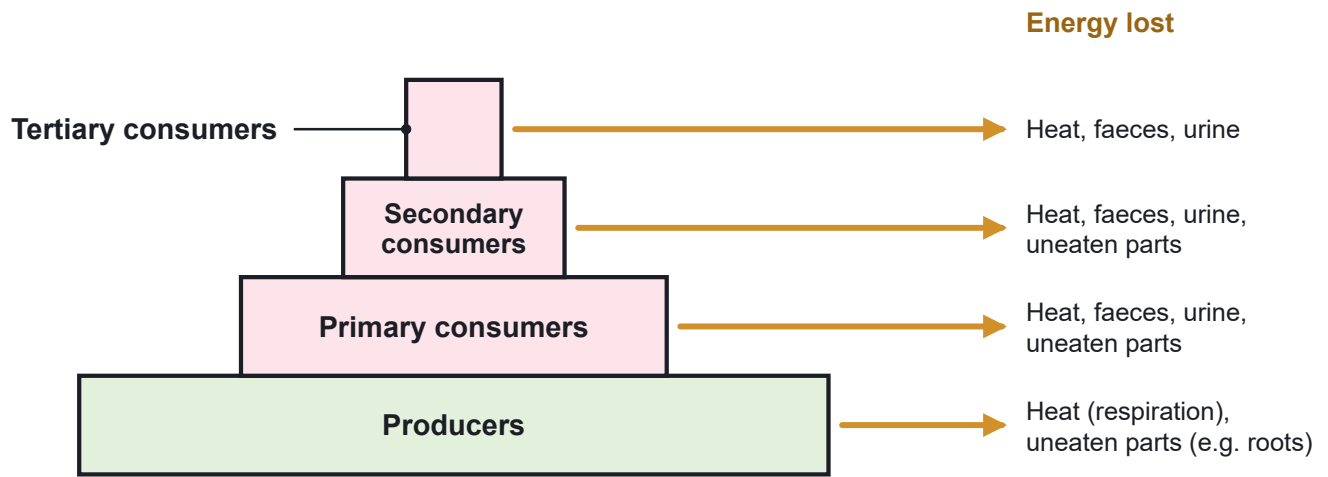
The grass in a field stores 20 000 kJ of energy. The rabbits that eat the grass gain 1800 kJ. Calculate the percentage of energy transferred from the grass to the rabbits.

1. Energy transferred = 1800 kJ.
2. Energy available = 20 000 kJ.
3. Percentage = $1800 \div 20\,000 \times 100 = 9\%$.

Answer: 9%

This has two effects. Less energy and biomass is available at each higher trophic level, so pyramids of biomass and energy narrow at each level. Food chains are **limited in length**, usually to four or five trophic levels, because there is too little energy left to support more.

Exam tip: Do not say that energy is used up. Say that it is transferred to the surroundings as heat, or to less useful forms, or lost in waste.



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A pyramid of biomass (not drawn to scale) gets narrower at each trophic level because energy is **lost to the surroundings** at every level.

Quick check

1. What number trophic level are producers?
2. Name the organisms that break down dead material.
3. What do the arrows in a food chain show?
4. What percentage of energy is transferred to the next trophic level?
5. Why are food chains limited in length?

3 Cycles within ecosystems Spec 4.10–4.11B

The carbon cycle Spec 4.10

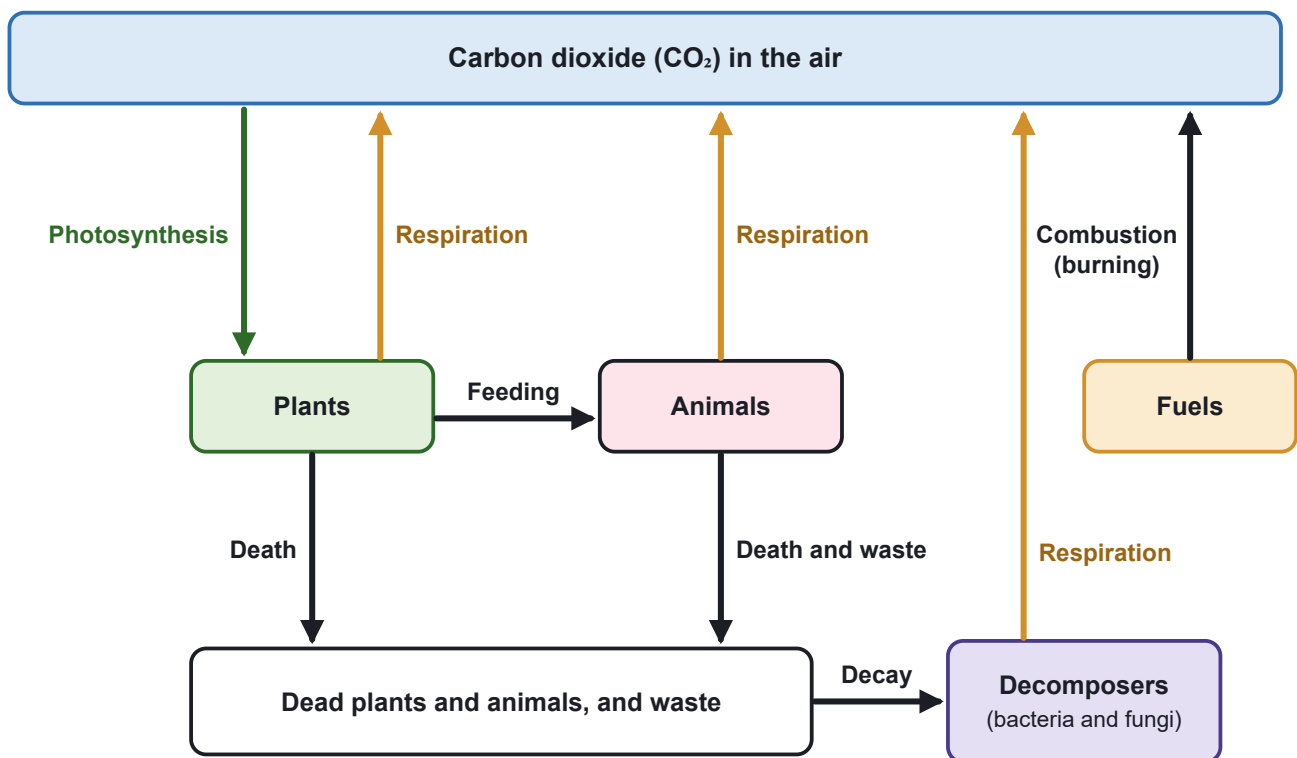
All living things are made of carbon compounds. The **carbon cycle** returns carbon to the atmosphere as carbon dioxide, so that it is available for plants to use in photosynthesis again. Carbon is also stored in fossil fuels, which are the remains of long-dead organisms.

1. Plants and algae take carbon dioxide from the air and use it in **photosynthesis** to make carbon compounds such as glucose, starch and proteins.
2. The carbon compounds pass along the food chain when animals feed.
3. All living organisms (plants, animals and decomposers) release carbon dioxide into the air by **respiration**.
4. When plants and animals die, and when they produce waste, **decomposition** by bacteria and fungi breaks down the material. The decomposers release carbon dioxide into the air by respiration.
5. Burning fuels such as wood, coal, oil and natural gas (**combustion**) releases carbon dioxide into the air.

The role of decomposers

Decomposers are bacteria and fungi. They break down dead plants, dead animals and waste, and they respire as they do so, releasing carbon dioxide. Without decomposers, dead material would pile up and the carbon in it would be locked away. The supply of carbon dioxide for photosynthesis would eventually run out.

Exam tip: Name the process at each arrow. Photosynthesis takes carbon dioxide out of the air. Respiration, decomposition and combustion put it back.



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The carbon cycle: **photosynthesis** takes carbon dioxide in; **respiration**, **decomposition** and **combustion** put it back.

Quick check

- 1 . Which process removes carbon dioxide from the air?
- 2 . Name three processes that return carbon dioxide to the air.
- 3 . Why are decomposers important in the carbon cycle?

4 Human influences on the environment Spec 4.12-4.18B

Air pollution: sulfur dioxide and carbon monoxide Spec 4.12

Burning fuels releases pollutant gases into the air. Two that you must know about are **sulfur dioxide** and **carbon monoxide**.

Sulfur dioxide (SO₂)

Sulfur dioxide is released when fossil fuels that contain sulfur, such as coal and oil, are burned (for example in power stations). It dissolves in rain water to form acidic solutions, so the rain becomes **acid rain**.

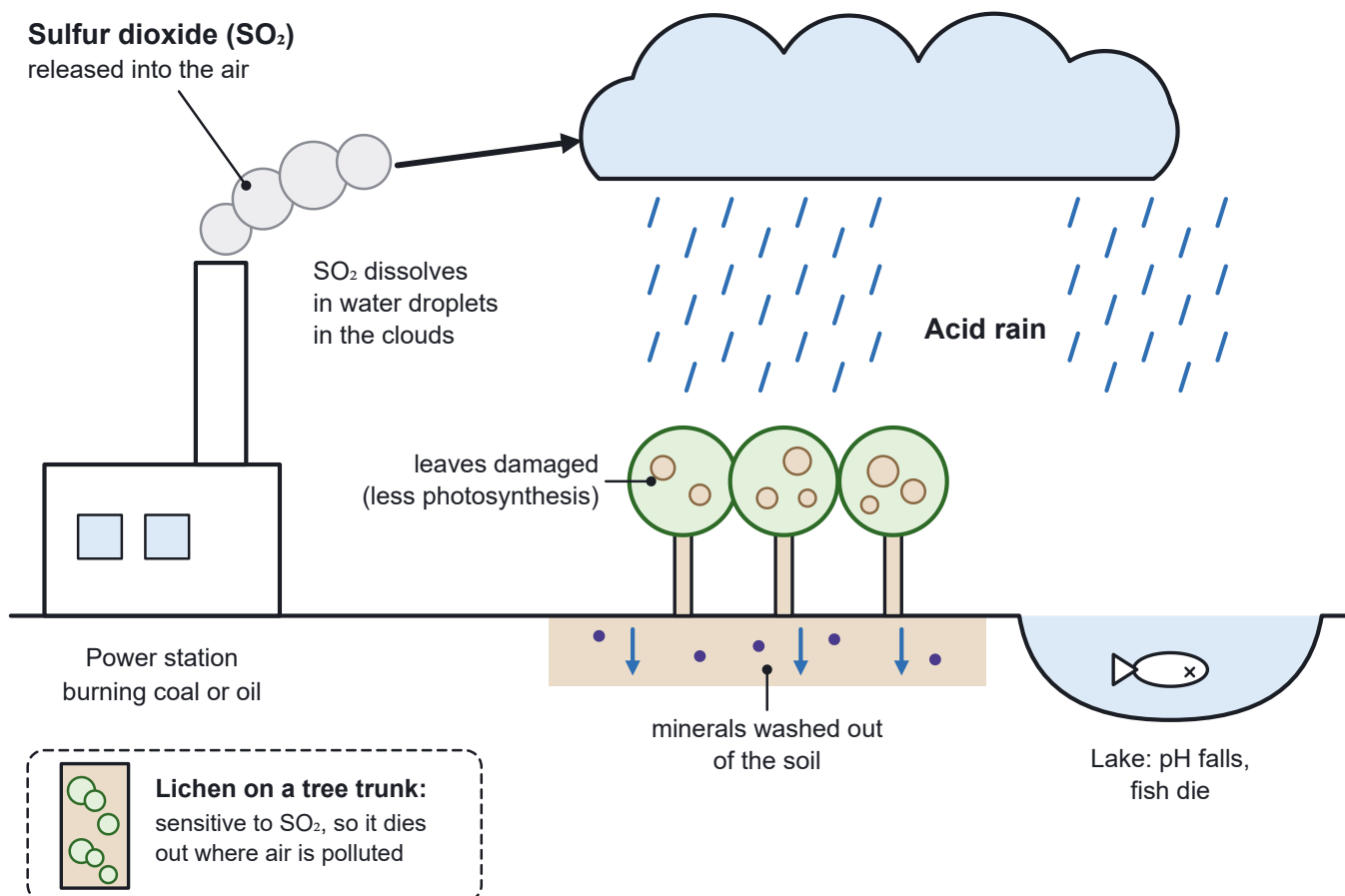
- Acid rain lowers the pH of lakes and rivers. Many fish and other aquatic organisms cannot survive in acidic water, so their numbers fall.
- Acid rain damages the leaves of trees, so they photosynthesise less. It also washes minerals out of the soil, so the trees grow poorly or die.
- Some lichens are very sensitive to sulfur dioxide, so they die out where the air is polluted. Their absence shows that the air is polluted.
- Sulfur dioxide gas also irritates the lungs and can cause breathing problems.

Carbon monoxide (CO)

Carbon monoxide is a poisonous gas formed by the **incomplete combustion** of carbon-containing fuels, when there is not enough oxygen. Sources include car engines and faulty gas heaters. It is colourless and has no smell.

- Carbon monoxide combines with **haemoglobin** in red blood cells, much more strongly than oxygen does.
- Haemoglobin that is combined with carbon monoxide cannot carry oxygen, so less oxygen is transported to the tissues.
- Cells then cannot respire aerobically enough. The effects are headaches, dizziness and fainting, and a high dose can cause death.

Exam tip: For carbon monoxide, link three ideas: it binds to haemoglobin, so less oxygen is carried, so less aerobic respiration. For sulfur dioxide, link it to acid rain and then to the effect on lakes or trees.



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Sulfur dioxide forms **acid rain**, which harms trees, soil and the organisms in lakes.

Greenhouse gases and human activities Spec 4.13, 4.14

The **greenhouse effect** keeps the Earth warm enough for life. The gases that cause it are called **greenhouse gases**. You must know five of them and how human activities add to them.

Greenhouse gases and human sources	
Greenhouse gas	How human activities add to it
Carbon dioxide (CO_2)	Burning fossil fuels in power stations, vehicles and homes; burning forests when land is cleared (deforestation, which also removes trees that take in CO_2)
Methane (CH_4)	Cattle and other farm animals, which release it from their digestion; rice paddy fields; rotting waste in landfill sites
Nitrous oxide (N_2O)	Use of nitrogen fertilisers on fields; burning fuels in vehicles
CFCs (chlorofluorocarbons)	Released from old refrigerators, air conditioners and aerosol sprays (CFCs are now banned in most countries)
Water vapour (H_2O)	Mostly from evaporation of water from oceans and land. Burning fuels also releases it, and a warmer atmosphere holds more of it.

Most of the increase in carbon dioxide over the last 200 years is from burning fossil fuels and deforestation. Methane and nitrous oxide increase as more land is farmed to feed a growing human population.

Exam tip: Give a specific source. 'Pollution' or 'factories' is too vague. Say 'burning fossil fuels' for carbon dioxide and 'cattle' or 'rice fields' for methane.

The enhanced greenhouse effect and global warming Spec 4.15

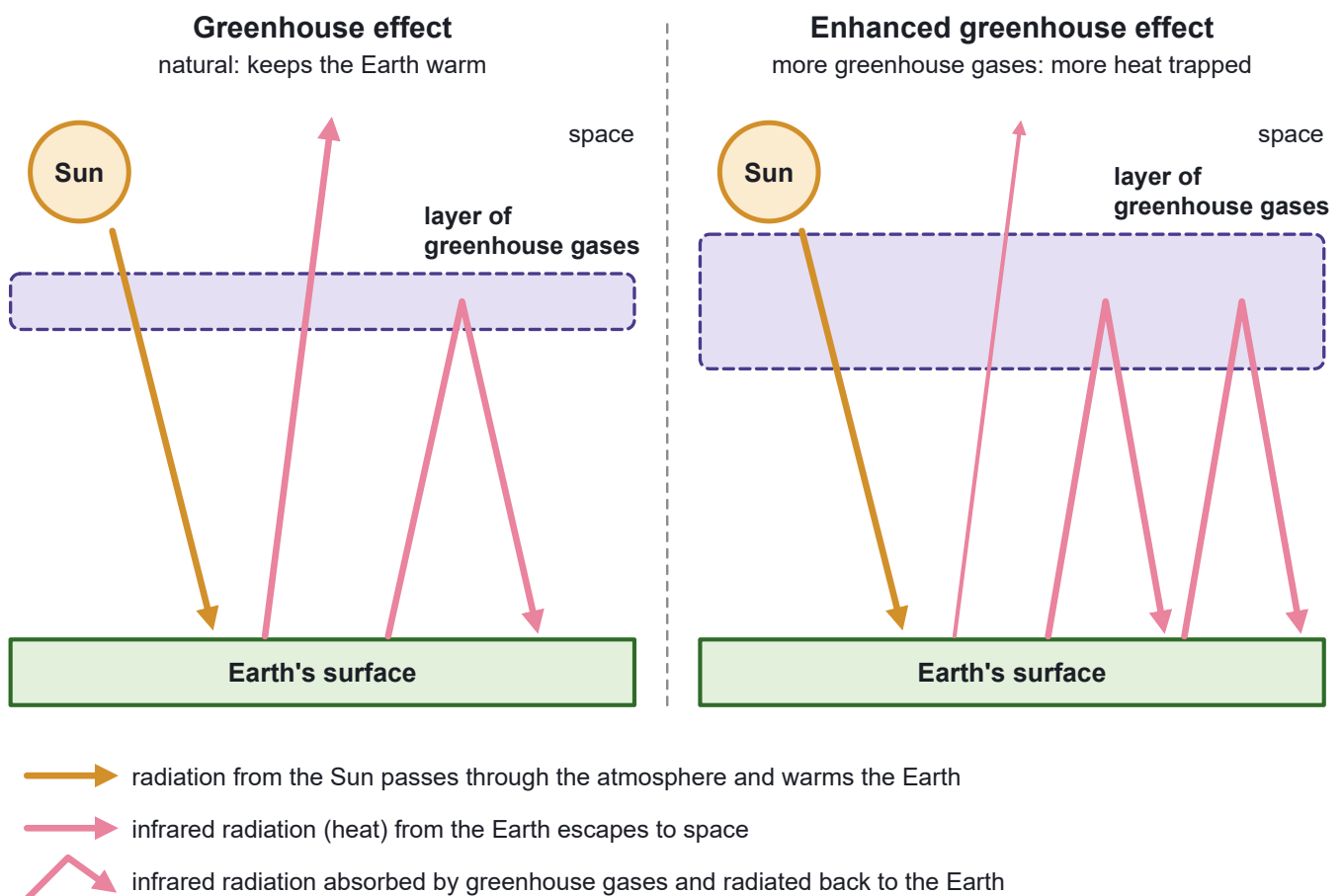
Some greenhouse effect is natural and necessary. The **enhanced greenhouse effect** is the extra warming caused by human activities that increase the amount of greenhouse gases.

1. Radiation from the Sun passes through the atmosphere and warms the surface of the Earth.
2. The warm Earth gives out **infrared radiation** (heat) towards space.
3. Greenhouse gases in the atmosphere absorb some of this infrared radiation and radiate it in all directions, including back towards the Earth. This keeps the Earth warm.
4. When humans increase the amount of greenhouse gases, more infrared radiation is absorbed and sent back to the Earth. This is the enhanced greenhouse effect.
5. The average temperature of the Earth's surface rises. This is **global warming**.

Possible consequences of global warming

- Ice caps and glaciers melt and the oceans expand as they warm, so sea levels rise. Low-lying coastal land can flood.
- Weather patterns change, with more extreme events such as droughts, floods and storms.
- Habitats change, so the distribution of species changes. Species that cannot move or adapt may become extinct, so biodiversity falls.
- Crop yields may change in some regions, which affects food production.

Common mistake: The greenhouse effect is not the same as the hole in the ozone layer. Do not mention ozone when explaining global warming.



Greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), CFCs and water vapour

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More greenhouse gases absorb **more infrared radiation**, so more heat is trapped and the Earth warms.

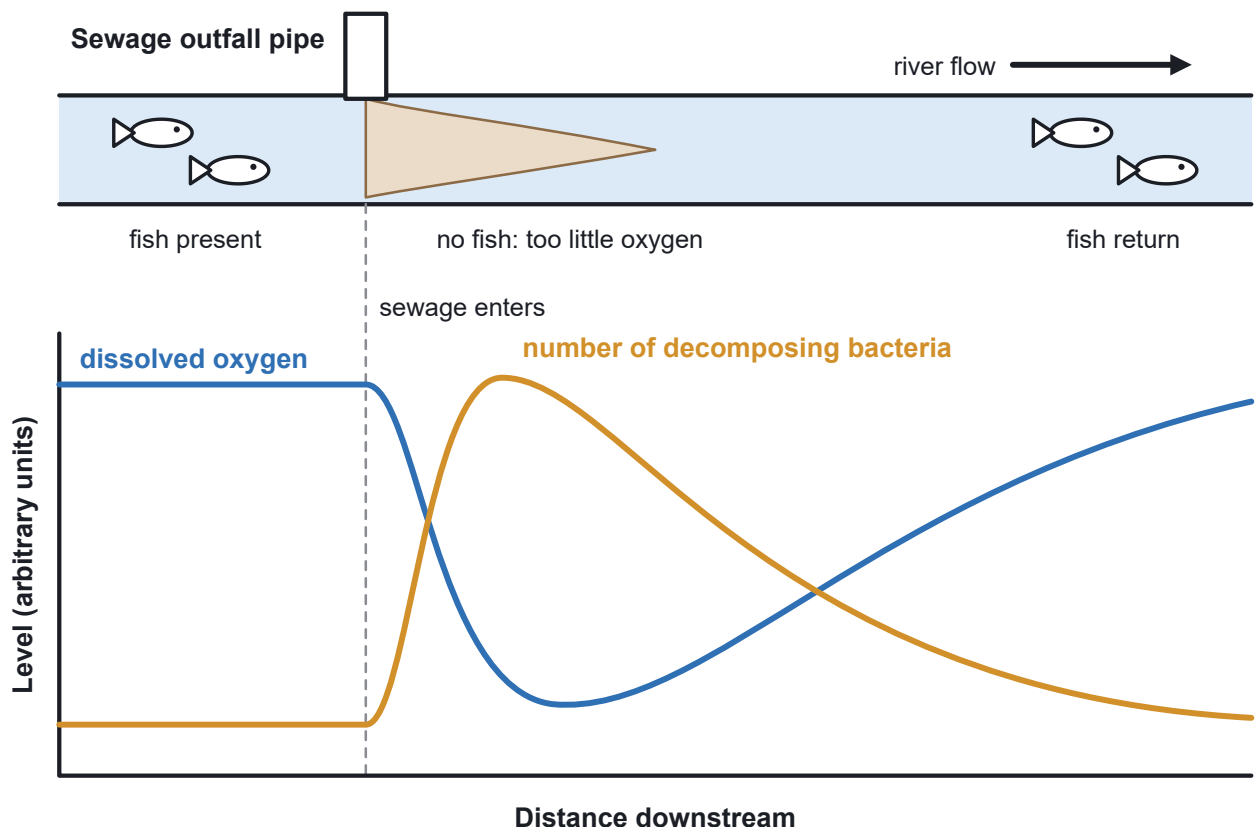
Water pollution by sewage Spec 4.16

Sewage is waste water from homes and industry. If it is released into rivers or lakes without proper treatment, it causes pollution with several biological consequences.

- Sewage contains a lot of organic matter. Bacteria and other decomposers feed on it and respire aerobically, so they use up the dissolved **oxygen** in the water.
- As the oxygen level falls, fish and other aquatic animals that need oxygen die. Only organisms that tolerate low oxygen survive, so biodiversity falls.
- Sewage contains **pathogens** (disease-causing microorganisms). People who drink the water or use it for washing food can catch diseases, such as cholera and typhoid.
- Sewage also contains nitrates and phosphates. These act as fertiliser for algae and can lead to eutrophication.

1. Untreated sewage enters the river.
2. Decomposers multiply, feeding on the organic matter.
3. The decomposers use up oxygen in aerobic respiration.
4. The oxygen concentration of the water falls.
5. Fish and other animals die, so the food web is disrupted.

Exam tip: The key link is: more decomposers, so more oxygen used, so less oxygen for fish. Do not just say the sewage poisons the fish.



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Decomposers feeding on the sewage **use up the dissolved oxygen**, so fish cannot survive just downstream.

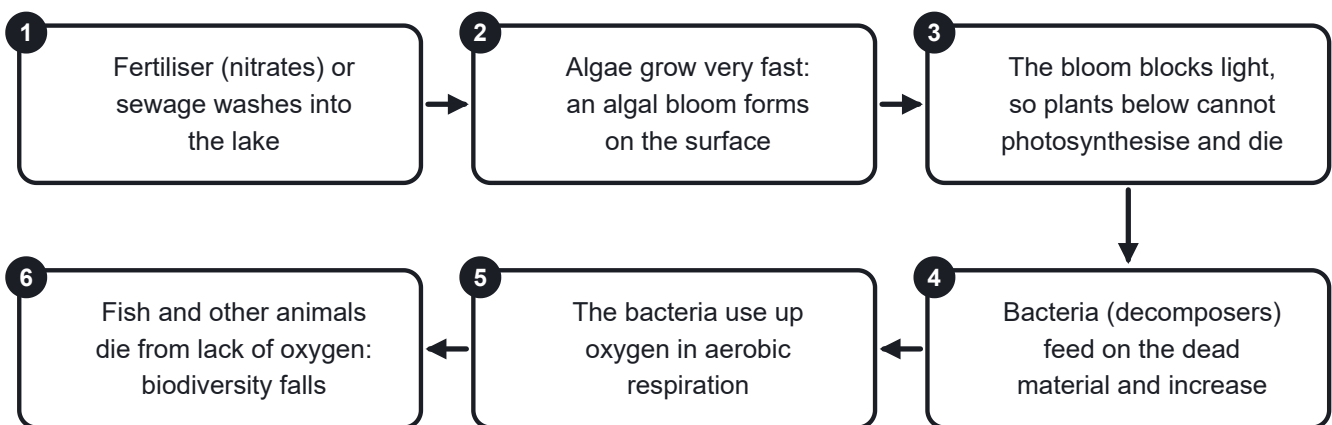
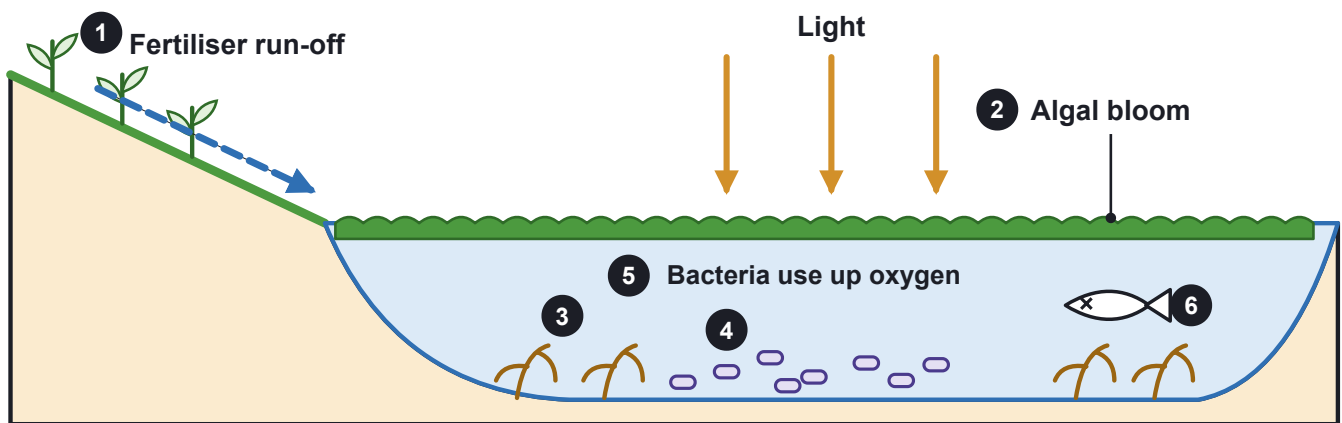
Eutrophication Spec 4.17

Eutrophication happens when too many mineral ions, such as nitrates and phosphates from fertilisers, enter lakes and rivers. **Leaching** is the washing of dissolved minerals out of the soil by rain. Fertiliser

that crops have not taken up is leached into streams and rivers.

1. Nitrates and other minerals from fertilisers are leached from fields into the water.
2. Algae in the water grow very quickly because of the extra minerals, forming a layer on the surface (an algal bloom).
3. The layer blocks light, so plants and algae lower down cannot photosynthesise and die.
4. Bacteria (decomposers) feed on the dead material and their numbers increase.
5. The bacteria use up oxygen in the water for aerobic respiration.
6. Fish and other aquatic animals die from lack of oxygen, so biodiversity falls.

Common mistake: The fish do not die because the algae poison them. The main cause is the decomposers feeding on the dead plants and algae, which use up the oxygen.



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Eutrophication: extra nitrates cause an algal bloom, plants die, **decomposers use up the oxygen** and fish die.

Quick check

1. What gas causes acid rain?
2. Why is carbon monoxide poisonous?
3. Name the five greenhouse gases in the spec.
4. Why does sewage pollution kill fish?

Quick check answers

The organism in the environment

1. All the organisms of one species living in the same area.
2. A community together with the non-living (abiotic) parts of its environment.
3. To avoid bias.
4. Competition and predation.

Feeding relationships

1. Level 1.
2. Decomposers.
3. The direction food and energy pass, from the food to the organism that eats it.
4. About 10%.
5. Too little energy is left to support more trophic levels.

Cycles within ecosystems

1. Photosynthesis.
2. Any three of: respiration, decomposition, combustion.
3. They break down dead material and release carbon dioxide by respiration.

Human influences on the environment

1. Sulfur dioxide.
2. It combines with haemoglobin, so the blood carries less oxygen.
3. Water vapour, carbon dioxide, nitrous oxide, methane and CFCs.
4. Decomposers feeding on it use up the oxygen in the water.